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(56) Documents Cited
GB 2270199 A EP 0420691 A2 US 5153889 A
US 5048035 A

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(54) **A light-emitting diode**

(57) In a light-emitting diode composed of indium gallium aluminium phosphide with a substrate 1, an electric contact 7 and a double heterostructure as active zone comprising a first coating layer 2, an active layer 3 and a second coating layer 4, a window layer 5 applied to said second outer layer, and an electric contact 6 applied to the window layer, the window layer consists of gallium aluminium phosphide. The aluminium content of the window layer 5 is between 0.1% and 50% and its thickness lies between 0.5 and 30µm.

window
Ga Al P

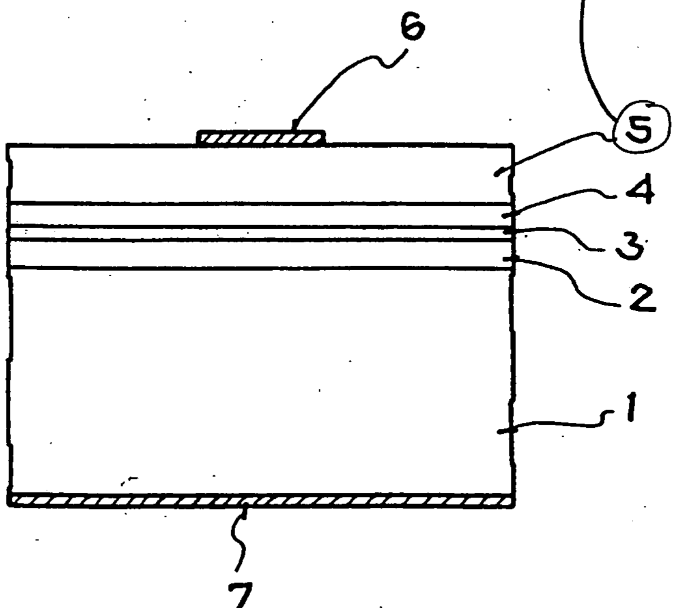

FIG.

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A Light-Emitting Diode

The invention relates to a light-emitting diode composed of indium gallium aluminium phosphide ((InGaAl)P) with a substrate, an electric contact to the substrate and a double heterostructure as active zone comprising a first outer layer, an active layer, a second outer layer, a window layer applied to said second outer layer and an electric contact applied to said window layer.

Light-emitting diodes (LEDs) are used i.a. for display and lighting purposes. They are characterised by a small size, compatibility with electronic systems, good robustness and reliability as well as a long life. In particular, light-emitting diodes composed of indium gallium aluminium phosphide ((InGaAl)P) are currently the brightest components of this type. They consist of an active layer with the composition In(0.48)Ga(0.52-x)Al(x)P, where x is selected in the range between 0.05 and 0.25 depending upon the desired colour and emission wavelength. Thus for example an Al content of $x = 0.05$ gives an orange-red emission of approximately 620 nm, a value of $x = 0.15$ gives a yellow emission of 590 nm and $x = 0.25$ gives a green emission of approximately 560 nm wavelength. This active layer is enclosed between two further layers of In(0.48)Ga(0.52-y)Al(y)P which have a higher Al content ($y > x$) and thus a greater band gap than the active layer. This arrangement consisting of three layers is known as a double heterostructure. When the In content is selected at 0.48, all three layers of the double heterostructure have the same

lattice constant as gallium arsenide (GaAs) and therefore can be epitaxially deposited upon a gallium arsenide substrate with good crystalline perfection. The man skilled in the art will also be aware that it is difficult and costly to produce layers of indium gallium aluminium phosphide (InGaAl)P with a relatively greater thickness and higher conductivity. For light-emitting diodes composed of this material this means that the current propagation from a, for example, circular surface contact to the entire cross-sectional surface of the diode is generally inadequate and therefore a substantial part of the light, which is mainly generated below the non-transparent contact, is lost. To reduce this loss, conventionally a further layer is applied above the double heterostructure, which further layer to the greatest possible extent is to be highly conductive and transparent to the generated light.

This so-called current propagation- and window layer is produced from various materials in the known light-emitting diodes. The publication in Applied Physics Letters 61 (1992) pp 1775-1777 describes a layer of Ga(0.2)Al(0.8)As. The authors of the publication in Electronic Letters 30 (1994) pp 1793-1794 use indium-tin-oxide (ITO). EP 0 434 233 describes a transparent window layer of gallium arsenide phosphide (GaAsP) or gallium phosphide (GaP). EP 0 627 772 describes a current propagation layer of gallium aluminium arsenide phosphide (GaAl)(AsP) which is adapted to the lattice constant of the underlying double heterostructure by means of a low phosphorus content of 0 to 8 %. Combinations of a plurality of different materials are also known, for example gallium aluminium arsenide (GaAl)As with a corrosion protection layer of indium gallium phosphide (InGa)P as proposed in EP 0 616 377. It is also known to produce this layer from gallium phosphide with an underlying GaAs buffer layer.

Although these known window layers substantially increase the brightness of the light-emitting diodes composed of indium gallium aluminium phosphide (InGaAl)P, all the previously used materials have specific disadvantages: gallium aluminium arsenide (GaAl)As is not sufficiently transparent for yellow and green emission and is not moisture-proof in the case of a higher aluminium content. Indium-tin-oxide (ITO) leads to too high a contact resistance, and gallium phosphida (GaP) also exhibits a notable absorption, in particular in the green spectral range.

Therefore the object of the present invention is to provide a material for the window layer which leads to an improved increase in the degree of brightness and ensures good environmental compatibility.

According to the present invention, there is provided a light-emitting diode composed of indium gallium aluminium phosphide ((InGaAl)P) with a substrate, an electric contact on the substrate and a double heterostructure as active zone, comprising a first coating layer, an active layer, a second coating layer, a window layer applied to said second coating layer and an electric contact applied to said window layer, wherein the window layer consists of gallium aluminium phosphide ((GaAl)P).

An exemplary embodiment is illustrated in the Figure. The Figure shows the structure of a light-emitting diode with window layer.

The double heterostructure is epitaxially deposited as active zone upon a substrate 1 of gallium arsenide GaAs and the electric contact 7 to the substrate 1. This double heterostructure consists of a first coating or protective layer 2 of In(0.48)Ga(0.12)Al(0.4)P, an active layer 3 of In(0.48)Ga(0.37)Al(0.15)P, and a second coating or protective layer 4 of In(0.48)Ga(0.12)Al(0.4). The window layer 5 of Ga(0.8)Al(0.2)P is epitaxally deposited on this second coating 4. Arranged on the window layer 5 is a further electric contact 6 which covers only a part of the upper side of the window layer 5. During the operation of the light-emitting diode

in this example an emission at a wave length of 590 nm (yellow) is released. During the operation of the light-emitting diode a current flows from the contact 6 to the contact 7 or vice versa depending upon the polarity of the diode, where current path from the contact 6 widens in the window layer 5 to the full cross-section of the diode. The polarity of the individual layers of the light-emitting diode here can be: substrate 1 n-conducting, first coating 2 n-conducting, active layer 3 n-conducting, second coating 4 p-conducting, window layer 5 p-conducting. In the case of the inverse conductivity type of the aforementioned layers, the current flows in the reverse direction.

Since, in accordance with the invention, the window layer 5 consists of gallium aluminium phosphide (GaA1)P, it possess a greater band gap than window layers according to the prior art and therefore absorbs less light so that the diode possesses a greater brightness. The aluminium content of the window layer here can range between 0.1 and 50%. Preferably, the thickness of the window layer is between 0.5 and 30 μm.

CLAIMS

1. A light-emitting diode composed of indium gallium aluminium phosphide ((InGaAl)P) with a substrate, an electric contact on the substrate and a double heterostructure as active zone, comprising a first coating layer, an active layer, a second coating layer, a window layer applied to said second coating layer and an electric contact applied to said window layer, wherein the window layer consists of gallium aluminium phosphide ((GaAl)P).

2. A light-emitting diode as claimed in Claim 1, wherein the aluminium content of the window layer amounts to between 0.1 % and 50%.

3. A light-emitting diode as claimed in Claim 1 or 2, wherein the thickness of the window layer amounts to between 0.5 and 30 μm.

4. A light-emitting diode substantially as herein described with reference to the accompanying drawings.

The Patent Office

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Application No: GB 9618872.7
Claims searched: All

Examiner: C.D.Stone
Date of search: 2 December 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): H1K(KEAA,KEAX,KELD)

Int Cl (Ed.6): H01L

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB2270199 A	MITSUBISHI CABLE INDUSTRIES (See Fig.3 and page 9 lines 16-22, page20 lines 5-18)	1
X	EP0420691 A2	TOSHIBA (See window layer 58 in Fig. 9)	1
X	US5153889	TOSHIBA (See window layer 73 in Fig.30)	1
X	US5048035	TOSHIBA (See window layer 26 Figs.3-5 and col.7 lines 39-41)	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		

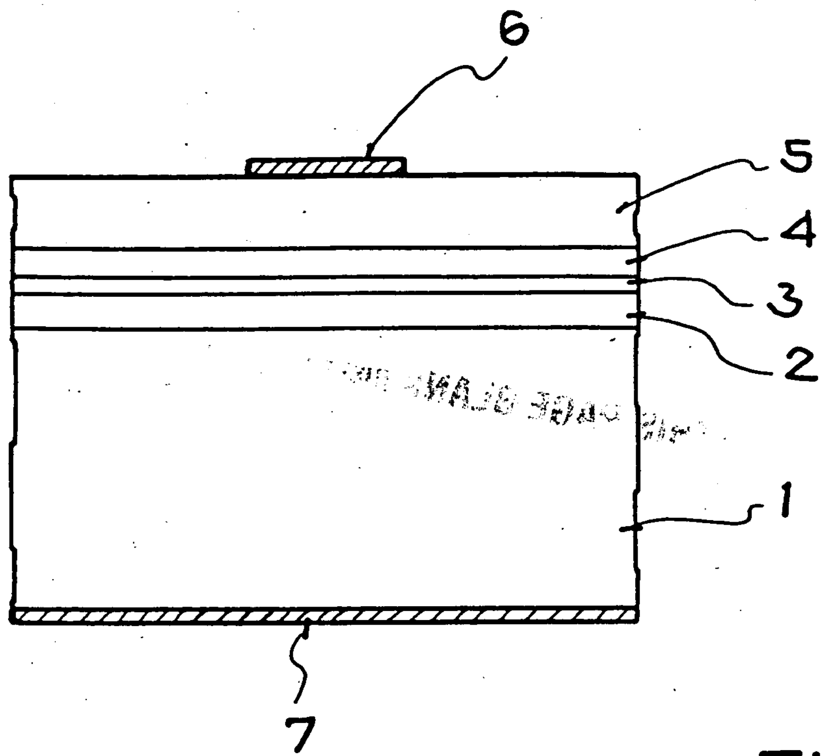

FIG.